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Integration of terrestrial laser scanning and spectral canopy scanner in horticulture applications

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Summary One of the most difficult challenge in the everyday practice to describe the canopy growing of fruit trees in an orchard. The photosynthetic activity is the basic of the primer production of plants. The measurement of leaf area and determination of the photosynthetic activity could be occurred with some elaborated methods between experimental conditions. In this article we present such an integrated methodology, which is ideal to determine the geometric and spectral characteristic of fruit trees between field conditions. We have carried out laser scanning technology to investigate the geometric-topological characteristics and parallel the active infra-red sensor to collect spectral data about an apple orchard. The surveys were worked out in an intensive apple orchard with drip irrigation system, protected by hail net in Study and Regional Research Farm of the University of Debrecen near Pallag. This study shows the filtering and interpretation methods of created data. The produced high accuracy data can be directly used in the precision horticulture. It could serve as a guiding data to implementation a future "virtual horticulture". Higher spatial and temporal resolution could help for a better recognition of water balance of orchards.

Key words: laser scanning, precision horticulture, spectral canopy mapping, apple orchard

Introduction

The apple production is a dynamically developing horticultural sector in the world, which increased average 2–4% yearly. This increase was occurred primarily due to the developing countries. In the developed countries, thus in the most European countries, the apple production is stagnate or decrease recently. Currently in Hungary less than 100,000 hectares of orchards can be found, from which apple is cultivated on one of the largest areas. Apple orchards cover about 60% of the total pomiculture in Hungary, although in the last period the production was reduced (*Gonda and Apati 2011*). The production of marketable horticulture products is difficult without quality horticulture practice, which in many cases is primary condition of appropriate management systems. Crown formation is very important from more aspects. The incoming light to the canopy, providing of the desired height and width of trees, optimize the crown habit are influenced by the pruning. But one of the main aims of pruning is to increase the productivity of the fruit trees (*Gonda és Fülep 2011*). In the most cases pruning is occurred by empirical data and anecdotal evidence from growers (empirical indices), but some researcher tried to describe the mathematical model of perennial woody plants, including fruit tree species to improve yields (*Xia et al., 2009*). Costes and Gu´edon (2002) modeled the branching patterns in case of young apple trees, but the bases of plant modeling were derived by Lindenmayer (1968). Lindenmayer used L-systems (Lindenmayer systems) to built a plant models were conceived as a mathematical theory of plant development. Creating models based on self-similar. These self-similar patterns are the fractals. The fractals are ideal for make shapes, which described with fractional dimension. The first fractal shape was made by Mandelbrot (1982). Some decades ago to the realistic visualization of plant structure have been needed for the developmental processes of computer graphics.

Presently, numerous high-tech instruments are available and contribute to recognize all of branches and leaves of trees in 3D. The leaf area depends on canopy structure (*Pokorn and Marek 2000*). The leaf area is a very important factor in some physiological processes. The photosynthesis and also the transpiration occur mainly within/through the leaves. The illumination of crown volume is very important, and with appropriate pruning techniques an optimal canopy structure can be formed to result a high quality yield production (*Robinson et al., 1993*).

The geometric-topological characteristics of trees can be determined by laser scanner technology. The LiDAR (light detection and ranging) system analyzes a real-world or object environment to collect data on its shape and possibly its appearance (e.g. color). Then the collected data can be used to construct digital, two-dimensional drawings or three-dimensional models useful for a wide variety of applications. The advantage of laser scanning is the fact that it can record huge numbers of points with high accuracy in a relatively short period of time (*Lerma García et al. 2008*). There are two kinds of laser scanners in horticulture applications. The airborne laser scanner could survey large horizontal areas. This technology is appropriate to the fast determination of canopy expansion based on the different echo times in an orchard. The terrestrial laser scanner is not so fast, but more accurate instrument compare to an airborne laser scanner. The measuring accuracy depends on the scanning methods (triangulation based, time-of-flight, phase based method) (*Tamás et al. 2011*).

The optimal nutrient management is very difficult in large horticulture areas. To determine values and local heterogeneity of the soil, the microclimate, the water supply is not easy with traditional methods. Some successful experiments were carried out in field conditions to define characteristics of plant which related to the photosynthetic active pigments. The photosynthetic activity determines the biomass production (*Ramachandra and Das 1986*), which changes not only in spatial, but in temporal (depend on the phenological stages). The available remote sensing instruments can measure the reflected part of the emitted energy from the leaves. The absorption and reflection of the solar radiation – or emitted light by an active sensor – are the result of relationship of the plants tissues, which are different by wavelengths (*Goel, 1988; Chen et al., 2000*). Chlorophyll absorbs markedly spectral range between 450–670 nm. Reaching infrared spectral range, the reflectance of healthy vegetation increases rapidly. Healthy vegetation reflects the 40–50% of the incoming energy between 700–1300 nm spectral ranges due to the internal structure of the leaves, it is influenced mainly by the lignin content of cell wall and the parenchyma structure (*Gates et al., 1965*). Traditional techniques and instruments of measurement of plant chlorophyll content require destructive point sampling that is costly, laborious, time consuming, and provide limited spatial coverage (*Gitelson and Merzyak 2004*). But nowadays there are several remote sensing instruments which define the reflectance characteristics of plant in non destructive and fast way.

The remote sensing is an efficient tool in shadowing of biomass production. It has the ability to create vegetation indices, which are correlated with the biomass. One of the most frequent indices is the Normalized Difference Vegetation Index which is used for the investigation of the surface coverage and biomass (*Neményi et al., 2010*). Using another bands of NIR and RED, other important information can be detected about the vegetation, such as leaf area (*Quan et al., 2005*), nitrogen supply (*Cabrera-Bosquet et al., 2011*), or the water content of plant tissue as well the Water Band Index (WBI) (*Gamon és Qiu 1999*; *Nagy et. al., 2010*).

Materials and methods

On 3rd September (fully developed canopy condition) we carried out a terrestrial 3D laser scanning measurement. The ScanStation C10 by Leica Geosystems uses the time-of-flight (TOF) principle for ranging. The light waves travel with a finite and constant velocity in a certain medium. Therefore, on the base of the time delay created by light travelling from a source to a reflective target surface and back to the source (round trip) their distance can be calculated. The scanner sweeps along the examined object with a green laser light. The laser beam deflection is occurred by a Smart X-Mirror™. We have surveyed one row of study area with 7 scan stations. The overlapping of scanning areas provided the unifying of point cloud, and increased the accuracy of measurement. The scan resolution was 8 mm on 10 m; it means that the accuracy was below 1 cm on the right side. The processing of raw point cloud was carried out by Leica Cyclone 7.1 and 3DReshaper software.

For further investigation of the fruit trees we used another active remote sensing instrument in data acquisition. On the 8th of November 2011 we carried out the measurement with GreenSeeker 505 vegetation indexmeter in Study and Regional Research Farm of the University of Debrecen near Pallag. The study area was an intensive apple orchard with drip irrigation system, protected by hail net. The weed coverage of the soil surface and the spectral characteristic of the canopy were investigated by the instrument. The most information was provided by the NDVI value. Because of the GreenSeeker 505 is an active remote sensing tool, it has got an internal light to calculating NDVI. The sensor operates by emitting light (red band and infared band) from the rectangular window onto a crop's canopy.

Reflected light from the canopy is focused on a detector behind the circular window. The system is calculated the NDVI form the given values, based the following equation:

$$NDVI = \frac{NIR - RED}{RED + NIR}$$

Both the rectangular and circular windows need to be free of any viewing obstructions when mounted. The data collecting was carried out 0.8–1 m from the soil surface and 50–100 cm from the foliage. As an interface of GreenSeeker 505 is working AgGPS FmX integrated display by Trimble, which has two built-in GNSS (GPS and GLONASS) to achieve more accuracy. The satellites signals are taken by an external AgGPS 25 antenna. Based on the longitude and latitude the NDVI values were summarized by the job computer. The data are simply downloaded via USB connection. Processing of data we have used the Surfer 10 software. The NDVI, the altitude and the speed values were saved the hardware of job computer in each second. Both the AgGPS FmX and the Greenseeker 505 were mounted on a tractor. The speed of tractor was 2.38 km/h, it could be determined the data of job computer. The speed of tractor was even, this verified the low standard deviation of speed data.

Results and discussion

The vegetation index measuring and laser scanning were carried out in Study and Regional Research Farm of the

University of Debrecen near Pallag. By the Greenseeker 505 collected data were processed and evaluated in Surfer 10 software environment. We have investigated the canopy NDVI values. From distance of 0.5-1 m were collected the data by the sensor. Based on the given NDVI map it could be established, where was higher the chlorophyll content (*Figure 1.*). The higher NDVI values shown, which trees have not felt they leaves yet, and/or which leaves have not decayed they chlorophyll content. The NDVI map was created an interpolation technique by Surfer 10 software. The interpolation is a mathematical approximately method to determine the unknown values based on the known values. The interpolation of spatial data were carried out with Krieging method.

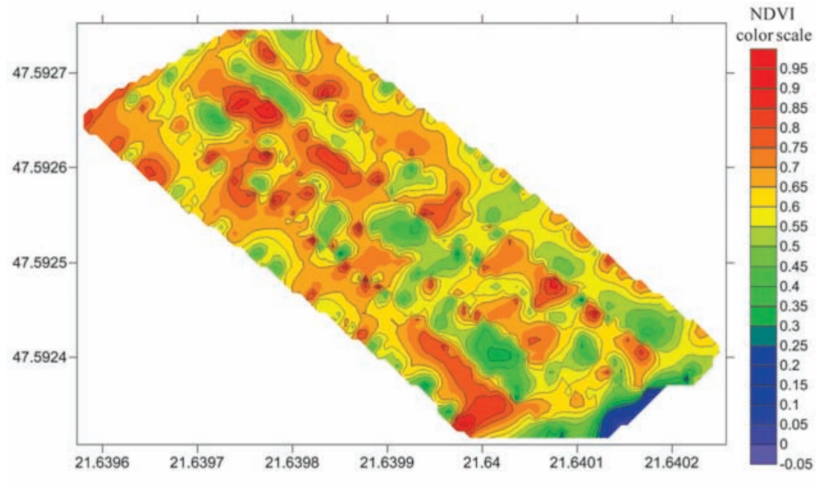

Figure 1: NDVI vegetation map of the hail protection net apple orchard

The laser scanning survey has given opportunities to determine the 3D structure of trees of the trees from the study area. We have modeled each tree to define the canopy expansion and the trunk diameter (*Figure 2.*). The parameters of chosen apple tree are the following: height of crown is 2.74 m, stem diameter is 3.4 cm.

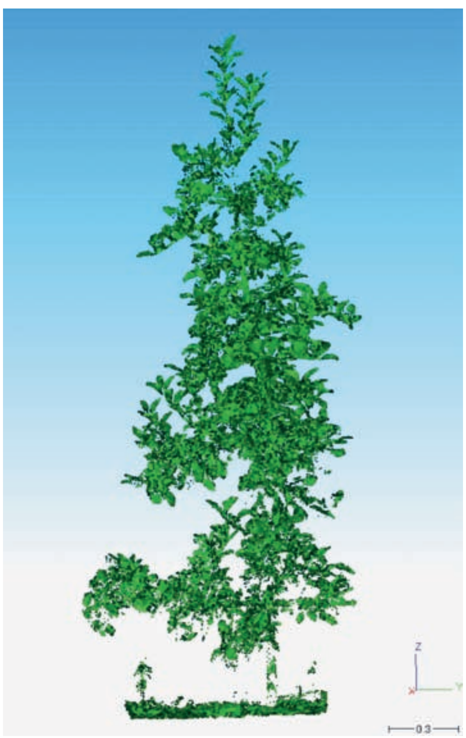

Figure 2: Model of a chosen apple tree

Conclusion

The results shown the used instruments were appropriate in horticulture applications. The vegetation activity of fruit trees and weeds could be detected, since there is a close correlation between NDVI and chlorophyll content, so it could be concluded health of the vegetation. Beside this, the NDVI could help in nutrient management and could support a precision pest management system. In the course of laser scanning we modeled in three dimensional of the fruit orchard. Further experiments are needed to recognize the canopy structure based on the combination of both high-tech instruments. The low NDVI values could mean a gap of the canopy, and a contactor could provide to get out more pesticide, where the NDVI is higher. The GreenSeeker could detect the weed flora of soil surface, so it could work out an energy and pesticide saving precision pest management system to reduce the environmental damage.

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References

Cabrera-Bosquet, L., Molero, G., Stellacci, A. M., Bort, J., Nogués, S., Araus, J. L. (2011): NDVI as a potential tool for predicting biomass, plant nitrogen content and growth in wheat genotypes subjected to different water and nitrogen conditions Cereal Research Communications, 39 (1):147–159.

Chen J. M., Li, X., Nilson, T., Strahler, A. (2000): Recent advances in geometrical optical modelling and its applications. *Remote Sensing Reviews,* 18: 227–262.

Costes, E., Gu´edon, Y. (2002): Modelling Branching Patterns on 1-year-old Trunks of SixApple Axillary Flowering Sequences. *Ann. Bot.,* 212: 481–520.

Gamon, J. A., Qiu, H. L. (1999): Ecological Applications of Remote Sensing at Multiple Scales. [In: Pugnaire, F. and F.

Valladares (eds), Handbook of Functional Plant Ecology.] Marcel Dekker, New York, 805–845.

Gates, D. M., Keegan, H. J., Schleter, J. C., Weidner, V. R. (1965): Spectral properties of plants. Applied Optics, 4: 11–20.

Gitelson, A. A., Merzyak, M. N. (2004): Non-destructive assessment of chlorophyll, carotenoid and anthocyanin content in higher plant leaves: Principles and algorithms. *Remote Sensing of Agriculture and the Environment*. 78–94.

Goel, N. S. (1988): Models of vegetation canopy reflectance and their use in estimation of biophysical parameters from reflectance data. *Remote Sensing Reviews,* 4:1–122

Gonda I., Apáti F. (2011): Almatermesztésünk helyzete és jövőbeni kilátásai. [In Tamás J. (szerk.) Almaültetvények vízkészlet-gazdálkodása.] Debreceni Egyetem, AGTC, Kutatási és Fejlesztési Intézet, Kecskeméti Főiskola, Kertészeti Főiskolai Kar, 13–25.

Gonda I., Fülep, I. (2011): Az almatermesztés technológiája. Debreceni Egyetem, AGTC, Kutatási és Fejlesztési Intézet, 260 p.

Lerma García, J. L., Van Genechten, B., Heine, E., Santana Quintero, M. (2008): Theory and practice on Terrestrial Laser Scanning. Editorial de la Universidad Politécnica de Valencia., Valencia, SPAIN. 261 p.

Lindenmayer, A. (1968): Mathematical models for cellular interaction in development, Parts I and II. *Journal of Theoretical Biology*, 18: 280–315.

Mandelbrot, B. B. (1982): The fractal geometry of nature. W. H. Freeman, San Francisco, 480 p.

Nagy A., Tamás J., Szabó Z., Soltész J., Nyéki J. (2010): Fejlett nem invazív technológiák alkalmazása almatermésűek vízkészlet-gazdálkodásának értékelésére. [In Kovács, Gy., Gelencsér, G., (szerk.) Élhető vidékért 2010. Környezetgazdálkodási Konferencia Természeti Erőforrásaink a Globális Környezeti Folyamatok Tükrében], 325–331.

Neményi M., Tamás J., Fenyvesi L., Milics G. (2010): A távérzékelés alkalmazása a biomassza és a vízkészletek mennyiségének, valamint minőségének megállapításánál. Klíma-21 Füzetek, 59. Klímaváltozás-Hatások-Válaszok. MTA-KSZI Klímavédelmi Kutatások Koordinációs Iroda, Budapest, 51–60.

Pokorn , R., Marek, M. V. (2000): Test of Accuracy of LAI Estimation by LAI-2000 under Artificially Changed Leaf to Wood Area Proportions. *Biologia Plantarium*, 43 (4): 537–544.

Quan, W., Adikua, S., Tenhunena, J., Granierb, A. (2005): On the relationship of NDVI with leaf area index in a deciduous forest site. Remote Sensing of Environment, 94: 244–255.

Ramachandra, A. R., Das, V. S. R. (1986): Correlation between biomass production and net photosynthetic rates and kinetic properties of RuBP carcoxylase in certain C3 plants. *Biomass*., 10: 157–164.

Robinson, T. L., Wünsche, J., Lakso, A. N. (1993): The influence of orchard system and pruning severity on yield, light interception, conversion efficiency, partitioning index and leaf area index. *Acta Horticulturae*, 349: 123–127.

Tamás, J., Riczu, P., Nagy, G., Nagy, A., Fórián, T., Jancsó, T., Szabó, Z. (2011): Applicability of 3D laser scanning in precision horticulture. *International Journal of Horticultural Science*, 17 (4–5): 55-58.

Xia, N., Li, A-S., Huang, D-F. (2009): Virtual Apple Tree Pruning in Horticultural Education. Learning by playing. Game-based education system design and development, 56 (70): 26–37.